PCT/IL 99 / 00466

REC'D 08 OCT 1999
WIPO PCT

STATE PF ISRAEL

This is to certify that annexed bereto is a true copy of the documents as originally deposited with the patent application particulars of which are specified on the first page of the annex.

זאת לתעודה כי רצופים בזה העתקים נכונים של המסמכים שהופקדו לכתחילה עם הבקשה לפטנט לפי הפרטים הרשומים בעמוד הראשון של הנספח.

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

This 29-08-1999 היום

ממונה על הבוחנים

רשם הפטנטים
Registrar of Patents

נתאשר

חוק הפטנטים, התשכ"ז - 1967
PATENTS LAW, 5727 - 1967

Application For Patent - בקשה לפטנט

לשימוש הלשכה
For Office Use

125964	מספר: Number
27-08-1998	תאריך: Date
	הוקדם/נדחה Ante/Post-dated

אני, (שם המבקש, מענו ולגבי גוף מאוגד - מקום התאגדותו)
I, (Name and address of applicant, and in case of body corporate - place of incorporation)

OFER DU-NOUR
2 Haoren Street
Timrat 28340
Israel

עופר דנור
רחוב האורן 2
תמרת 28340

Israeli Citizen

אזרח ישראלי

בעל אמצאה מכח **היותו הממציא** ששמה הוא
Owner, by virtue of **being the Inventor** of an invention the title of which is

(בעברית) (Hebrew)
התקן ושיטה למדידת עובי של שכבות ובמיוחד של ציפוי פוטורזיסט על פרוסות חצאי מוליכים

(באנגלית) (English)
METHOD AND APPARATUS FOR MEASURING THE THICKNESS OF A FILM, PARTICULARLY OF A PHOTORESIST FILM ON A SEMICONDUCTOR SUBSTRATE

*בקשת חלוקה - Application of Division	*בקשת פטנט מוסף - Application for Patent Addition	דרישה דין קדימה Priority Claim		
*מבקשת פטנט from Application	*לבקשה/לפטנט to Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האגוד Convention Country
No............................מס' dated.......................מיום	No............................מס' dated.......................מיום			

יפוי-כח: **כללי / עוד יוגש**
POA: **general/to be filed later**

filed in case הוגש בענין

המען למסירת מסמכים בישראל
Address for Service in Israel

איתן, פרל, לצר וכהן-צדק
עורכי דין, עורכי פטנטים ונוטריון
רח' משכית 22, א.ת. הרצליה 46733

היום 27 לחודש אוגוסט שנת 1998
This 27 of August of the year 1998

Signature of the Applicant חתימת המבקש

עבור המבקש,

איתן, פרל, לצר וכהן-צדק
עורכי דין, עורכי פטנטים ונוטריון
P-1805-IL

לשימוש הלשכה
For Official Use

טופס זה, כשהוא מוטבע בחותם לשכת הפטנטים ומושלם במספר ובתאריך ההגשה, הנו אישור להגשת הבקשה שפרטיה רשומים לעיל.
This form, impressed with the Seal of the Patent Office and indicating the number and date of filing, certifies the filing of the application the particulars of which are set out above.

Delete whatever is inapplicable מחק את המיותר *

METHOD AND APPARATUS FOR MEASURING THE THICKNESS OF A FILM, PARTICULARLY OF A PHOTORESIST FILM ON A SEMICONDUCTOR SUBSTRATE

התקן ושיטה למדידת עובי של שכבות ובמיוחד של ציפוי פוטורזיסט
על פרוסות חצאי מוליכים

Eitan, Pearl, Latzer & Cohen Zedek
Advocates, Patent Attorneys & Notaries
P-1805-IL

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for measuring the thickness of a transparent film on a substrate. The invention is particularly useful in measuring thickness variations of a photoresist film on a semiconductor substrate, and is therefore described below with respect to this application.

A typical semiconductor manufacturing process uses more than 17 photolithography steps. In each step, a photoresist (PR) material is deposited on the semiconductor (e.g., silicon wafer) surface, and an optical process is used to copy patterns onto the PR. The patterned PR is then used as a masking layer for subsequent process steps, such as etching, implanting, depositing, scribing, grinding, etc.

A photolithography process includes the following steps:

a) film, wherein the PR layer is coated uniformly over the wafer;

b) baking, wherein the PR is baked at a moderate temperature to dry the solvents therein;

c) exposing, wherein the wafer is exposed through a mask in which the required pattern appears as a non-transparent printing;

d) developing, wherein a chemical process is applied to remove the non-exposed PR from the wafer; and.

e) post exposure baking, wherein the wafers are baked after the exposure.

The photolithography process is one of the most challenging technologies used in the semiconductor industry. The patterns printed in the critical layers set the dimensional limitations for the entire technology. The minimum line width achieved today in production is 0.18μm (1/1,000 mm); the next generation of technologies is expected to require minimum line width of 0.1μm and below.

To achieve the minimum line width with high uniformity within each wafer and from wafer to wafer, it is most important to control each and every parameter in the photolithography process. Exposure energy, PR chemical composition, development time and baking temperature are only a few of the parameters that can affect the final critical dimension (CD) and its uniformity.

One of the most critical parameters to be controlled is the PR thickness. Because of the optical nature of photolithography, fluctuations of

several nano-meters in the layer thickness can have a substantial effect on the final CD.

In the current processes, the PR film is applied on a high speed spinning chuck, called a "spinner". The wafer is placed on the spinning chuck and is rotated at low speed while the PR is dispensed at the center of the wafer. After dispensing, the chuck is rotated at a high speed (300-5000 RPM). The centrifugal forces acting on the PR cause the PR liquid to flow towards the edge of the wafer. Most of the PR (ca. 90%) is spilled off the wafer and collected in a bowl to be drained later. The adhesion forces between the wafer surface and the PR hold a smaller amount of the PR on the wafer. The final thickness is a function of the centrifugal forces, the adhesion to the surface, and the shear forces caused by the viscosity of the liquid. The viscosity is increased during the spin due to the solvents evaporation therefore the solvents evaporation rate affects also the final thickness.

To control the final thickness one should control the rotational speed, the ramp-up speed("acceleration"), the PR viscosity, and the environmental conditions within the bowl, among other parameters.

Today, the process is set up and controlled by running a flat test wafer and measuring the final thickness, and thickness uniformity, by a stand-alone layer-thickness measurement device. In order to ensure process stability, a periodic test is done on the test wafer. If the thickness drifts out of the control limits, the production is stopped and corrective actions are taken to bring the final thickness back to target.

The above-described thickness monitoring procedures are inefficient and wasteful. They can cause serious delays in reacting to a process out of control (OOC). Test wafers and PR, as well as operational and engineering time, are spent in running the tests in a stand-alone system. Machine operational time is also wasted when the processing of production wafers is held up until positive test results are obtained. If the test results are negative, reworking may be required, or a complete batch may have to be scrapped.

Moreover, in contrast to the test wafers used for measurement purposes, the real production wafers have a much more complicated topography below the PR layer. As can be seen from FIG. 1, there may be a large difference in the thickness at different places (Th1-Th3), which differences are not reflected in a flat test wafer measurement.

In addition, since most of the PR ends up in the bowl, a considerable quantity of PR material is wasted. PR is one of the most expensive materials in the semiconductor process and will probably be even more expensive when deep-UV lithography is implemented in future production processes.

OBJECTS AND BRIEF SUMMARY OF THE PRESENT INVENTION

An object of the present invention is to provide an improved method and apparatus for measuring the thickness of a transparent film. Another object is to provide a method and apparatus which are particularly useful in measuring thickness variations in photoresist films on semiconductor substrates to avoid many of the above described drawbacks in the existing method and apparatus.

According to one broad aspect of the present invention, there is provided a method of measuring thickness variations of a transparent film on a substrate, comprising:

illuminating the film with a beam of light of multiple wavelengths;

detecting the intensity of the light reflected from the transparent film for each wavelength;

producing a signal defining the variation of the intensity of the detected light as a function of the wavelength of the detected light.

applying a Fourier Transformation to said signal to produce a series of Fourier coefficients for the signal frequencies of the Fourier Transformation; and

determining from said Fourier coefficients the thickness of the transparent film for each respective signal frequency.

According to further features in the preferred embodiment of the invention described below, the film is a transparent coating on a semiconductor substrate, preferably on a die among a plurality of dies carried on a semiconductor wafer. As will be described below, a number of advantages are obtained when the beam of light is large enough to cover a complete die.

According to another aspect of the present invention, there is provided apparatus for measuring the thickness of a transparent film on the substrate in accordance with the above method.

As will also be described below, the method and apparatus of the present invention are particularly useful for measuring thickness variations of a film *in situ,* and in real time, e.g., to control the application of a photoresist coating onto a semiconductor substrates, or to control the removal of such a film from the semiconductor substrate.

Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 schematically illustrates a typical wafer topography to receive a photoresist film of varying thicknesses, which topography is particularly suited for measuring by the method and apparatus of the present invention;

FIG. 2 is a diagram illustrating the reflectance diffraction of a thin layer, which diagram will be referred to in describing the basic theory of the present invention;

FIG. 3 illustrates one example of an apparatus constructed to measure the thickness of a photoresist film in accordance with the present invention;

FIG. 4 is an enlarged, side-elevational view of a part of the apparatus of FIG. 3;

FIG. 5 is a top plan view of the part of the apparatus illustrated in FIG. 4;

FIG. 6 is a flow chart illustrating the basic operations in controlling a photoresist film applicator in accordance with the thickness measurements by the present invention;

FIG. 7 and FIG. 8 are curves helpful in explaining the basic theory of the present invention; and

FIG. 9 and FIG. 10 are further curves illustrating the correlation between actual measurements in accordance with the present invention and computer simulated measurements.

BASIC THEORY OF OPERATION

As indicated above, the method and apparatus of the present invention are particularly suitable for measuring the thickness of a transparent film, particularly a photoresist film, where there are differences in thickness at different places of the substrate, as illustrated in FIG. 1. Thus, FIG. 1 illustrates three different photoresist film thicknesses Th1-Th3 in a typical wafer. These differences in thickness would not be accurately measurable in a conventional measurement. The method and apparatus of the present invention, however, are capable of measuring such thickness variations in an applied or removed coating, *in situ* and in real-time. The following description of the basic theory of operation of the present invention will be helpful in understanding how this is done.

Several methods are known for measuring thickness of transparent films using the reflected pattern of multi-wavelength light. Thus, as shown in FIG. 2, when a monochromatic (single wavelength) light beam arrives at a transparent film, part of the beam is reflected from the upper face (air/film interface), and part is reflected from the bottom face (film A / film B interface). FIG. 2 illustrates the above, wherein:

λ is the wavelength of the monochromatic light;

$\phi\varphi_o$ is the phase angle of the incident light (and of the light reflected from the air/A interface):

$\phi_o + \phi\varphi_a$ is the phase angle of the light reflected from the A/B interface;

r_a is the reflection coefficient of the air/A interface;

r_b is the reflection coefficient of the A/B interfaces; and

I is the intensity of the incident light

$$I = Io \cos(2\pi/\lambda\ t + \phi_o) \qquad \text{(EQ.1)}$$

For light arriving perpendicularly to the film surface, the reflection coefficient from the top and bottom surfaces are:

$$r_A = \frac{n_A - 1}{n_A + 1} \qquad r_B = \frac{n_B - n_A}{n_B + n_A} \qquad \text{(EQ. 2)}$$

wherein n_A, n_B are the refractive indices of layers A and B, respectively.

The light reflected from the upper face interferes with the light reflected from the bottom face, giving a reflection coefficient (R) which is a function of the layer thickness and the layer refractive index.

$$R = \frac{r_A^2 + r_B^2 + r_A r_B \cos 2\phi_A}{1 + r_A^2 r_B^2 + 2 r_A r_B \cos 2\phi_A} \qquad \text{(EQ. 3)}$$

where:

$\phi_A = 2\pi n_A d/\lambda$
d = layer thickness.

Illuminating the film with multi-wavelength light (white light), and measuring the reflectance at each wavelength (λ), will give R as a function of λ, i.e., $R(\lambda)$.

A Fourier Transformation enables any periodic function f(t) with a period of T_1 to be described, as a sum of Cosine and Sine functions:

$$f(t)= B_o + \Sigma A_n \operatorname{Sin}(nw_1 t) + \Sigma B_n \operatorname{Cos}(nw_1 t) \qquad \text{(EQ. 4)}$$

where:

$$w_1 = 2\pi T_1 \qquad \text{(EQ. 5)}$$

The coefficients A_n and B_n are called the Fourier coefficients of the function f(t).

Applying a Fourier Transformation to a signal representing such a function will give the Fourier coefficients as a function of the signal frequency

$$F(f(t)) = F(W) \qquad \text{(EQ. 6)}$$

It is obvious that if f(t) (EQ. 4) is a pure cosine function:

$$F(t) = A\cos(w_1 t) \qquad \text{(EQ. 7)}$$

then its Fourier Transformation F(f(t)) will result only in one non-zero coefficient at the frequency W_1, f(t) is a sum of cosine functions, then F (f(t)) will result in non-zero coefficients at the frequencies of those cosines.

Measuring the photoresist thickness of a product wafer having a complex topography produces a set of discrete thicknesses all included within the light beam. Each film thickness generates a reflection pattern for the film thickness. The total reflected beam is a combination of all those reflection patterns.

$$R(\lambda, d_1, d_2 --d_n) = \sum \frac{r_A^2 + r_B^2 + r_A r_B \cos 2\phi_n}{1 + r_A^2 r_B^2 + 2 r_A r_B \cos 2\phi_n} \qquad \text{(EQ. 8)}$$

Applying the Fourier Transformation to the signal representing the total reflected beam will, therefore, produce a series of Fourier Coefficients for the signal frequencies of the Fourier Transformation, from which the thickness of the transparent film for each respective signal frequency can be determined.

The parts combining the reflection function (EQ. 8) are close to pure cosine functions, therefore the Fourier Transformation of the reflection function

will give the largest coefficient at frequency φ_n. The thickness d_n can be calculated from φ_n and EQ. 3.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIGS. 3-5 schematically illustrate one set-up which may be used for measuring the thickness variations of a transparent photoresist film on a semiconductor substrate in accordance with the present invention. Such a set-up includes a spinner system 2, (FIG. 3), comprising a spinner chuck 3 for receiving the wafer W, and a motor 4 having an encoder 5, for rotating the chuck, and the wafer thereon, while a photoresist applicator 6 (FIG. 4) dispenses the photoresist material at the centre of the wafer. The wafer W is first rotated at a low speed as the photoresist material is dispensed at its centre, and then is rotated at a high speed (e. g., 300-5000 rpm) by electric motor 4, which produces centrifugal forces causing the photoresist liquid to flow towards the edge of the wafer W. Most of the photoresist (e.g. about 90%) is spilled off the wafer and is collected in a bowl 1 (FIG. 4) to be drained later, while the adhesion forces between the wafer surface and the photoresist hold smaller amounts of the photoresist as a film 8 on the wafer. As briefly described earlier, the final thickness of the photoresist film 8 is produced when a balance is achieved between the centrifugal forces, the adhesion to the surface, and the shear forces caused by the viscosity of the photoresist liquid. During the spinning process, the solvent contained in the photoresist evaporates and the viscosity increases. Therefore the final thickness is also a function of the

solvents evaporation rate which is affected by the temperature, air flow and other environmental conditions.

As illustrated in FIGS. 3-5, the apparatus further includes an illuminating device for illuminating the photoresist film 8 with a beam of light of multiple wavelengths (white light), and a detector for detecting the intensity of the light reflected from the photoresist film 8 for each wavelength.

The illuminating device is schematically shown at 10 in FIG. 3. It applies a beam of white light in any suitable manner, e.g., via an optical fiber 11, to an optical head 12 mounted above the wafer W to project a beam of light 13 onto the photoresist film 8 of the wafer W as the wafer is rotated. The light reflected from the photoresist film 8 is directed in any suitable manner, e.g., via another optical fiber 14, to a spectrum analyzer 15 for detecting the intensity of the light reflected from the photoresist film 8 for each wavelength.

Spectrum analyzer 15 is schematically illustrated in FIG. 4 as being of the type including a photodiode array. Such an array includes a micro-grating that splits the light beam to its spectral components, and a photodiode detector for each wavelength. The outputs of the photodiode array will be in the form of electrical signals representing the intensity of the light reflected from the photoresist film for each wavelength.

The outputs of the spectrum analyzer 15 are fed to a processor 16 which processors these outputs according to the basic theory of operation described above, and displays the outputs on a screen 17. In addition, an output of processor 16 may also be used for controlling the application of the photoresist film 8 onto the wafer W, as shown by the feedback line 18 from the

processor 16 to the motor 4 of the spinner system. e.g. for controlling its rotational speed to control the centrifugal forces applied to the photoresist film. It will be appreciated, however, that the output from processor 16 could be used for other feed-back controls, e.g., for controlling the rate of application of the photoresist film to the wafer via applicator 6.

As shown schematically in FIGS. 4 and 5, the optical head 12 is mounted, via an arm 20, for movement along the R-axis, to enable the optical head to be located at any selected radius of the wafer W under test. During the wafer rotation the angular position of the wafer is identified by the encoder 5 thus, combined with the R position, gives the location of the measurement spot on the wafer. Preferably, the beam of light 13 is large enough to cover at least one complete die of the plurality of dies carried by the wafer W, as schematically shown in FIG. 5. The use of such a beam of light large enough to cover a complete die, or a multiple thereof, provides a number of advantages. Thus, it better assures that the combined reflected light detected by spectrum analyzer 15 will not change substantially between measurements, irrespective of differences in exact measurement position. Further, the large spot size increases the signal collected by the detector and also increases the speed of detection. Using a large spot size is contrary to the current trends in layer thickness measurement systems which systems use small spot sizes in order to detect different thicknesses.

The flow chart of FIG. 6 illustrates one manner of using the above-described apparatus for measuring the thickness of the photoresist film 8 *in situ* at the time of application of the photoresist film, and also for controlling

the application of the photoresist film. As shown in FIG. 6, the wafer W is first loaded on the spinner chuck 3 (block 30), and the photoresist material is dispensed from the applicator 6 at the centre of the wafer (block 31), as the wafer is rotated by the spinner motor 4 (block 32). An initial measurement of the photoresist film is made (block 33), and subsequent measures are periodically made (blocks 34 and 35), under the control of the rotary encoder 5 of the spinner motor 4. When the desired thicknesses are obtained, as determined by the processor 16, the processor terminates the operation of the spinner motor 4, via the feed-back line 18 (FIG. 3).

FIG. 7 illustrates a simulation the above-described process when applied to a wafer coated with a photoresist film of two thicknesses (d_1, d_2). FIG. 6 thus illustrates the reflectance coefficient R_1 as a function of wavelength and thickness d_1, the reflectance coefficient of R_2 as a function of wavelength d_2; and the total reflectance R as a function of the two reflectance coefficients R_1 and R_2. In this example $d_1 = 0.65\mu$; $d_2 = 1.04\mu$, and f (the ratio of the intensity of the separated signals = 0.4.

FIG. 8 illustrates the results of applying a Fourier Transformation to the signal R defining the total reflection. This Transformation produces a series of Fourier Coefficients for the signal frequencies, from which the thickness of the transparent film can be determined for each respective signal frequency. As shown in FIG. 8, the two thicknesses of the photoresist film produced two peaks, each representing the Fourier coefficient of the thickness for the respective signal frequency.

FIG. 9 illustrates a measured reflection signal, as compared to a simulated reflection signal, based on a two thickness film, wherein it will be seen that the measured signal closely correlates to the simulated one. FIG. 10 compares the measured signal with simulated one after the Fourier Transformation has been applied, and also shows the close correlation between the two signals.

Preferably, the measurements should be taken while the wafer is spinning at typical speeds of 3000 - 5000 r.p.m. For a light spot at the edge of a 300 mm diameter wafer, the linear velocity would be about 70 m/sec. The photoresist thickness on the wafer changes gradually along tenth of mm; therefor an averaged result collected within a 10 mm-20 mm arc is sufficient. In order to receive a measurement resolution of 20 mm, the measurement speed should be about 0.3 mille second.

In order to achieve the required speed, it is preferably to use a parallel spectrometer detector 15. Such a spectrometer splits the light to its different wavelengths and directs them to the photodiode array, thereby measuring the intensity of each wavelength in parallel. Adding the detected the signals during several cycles can reduce the speed demand of the measurement by a factor of 10/30, and can improve the signal / noise ratio. The photoresist thickness may be changing at a rate of tenths of seconds, allowing enough margin for multi-cycle signal collection. Tracking of the wafer angular position would be performed by the rotary encoder 5 of the spinner motor 4.

The above-described method and apparatus may also be used for controlling the removal of a transparent film, e.g., by a reactive gas, by a

plasma process, by mechanical polishing, etc. The removal rate of a film can be controlled by continuously monitoring the thickness of the film in the manner described above during the removal process.

Other applications of the present invention will be apparent, for example, in the application or removal of intermetal dielectric layers, applied between two metal layers on a semiconductor substrate, or any other transparent layer, such as poly-imide. The invention could also be used in the application or removal of films on printed circuit boards or flat panel displays.

Further variations, modifications and applications of the invention will be apparent to those skilled in the art.

What is Claimed is:

1. A method of measuring thickness variations of a transparent film on a substrate, comprising:

illuminating the film with a beam of light of multiple wavelengths;

detecting the intensity of the light reflected from the transparent film for each wavelength;

producing a signal defining the variation of the intensity of the detected light as a function of the wavelength of the detected light;

applying a Fourier Transformation to said signal to produce a series of Fourier coefficients for the signal frequencies of the Fourier Transformation; and

determining from said Fourier coefficients the thickness of the transparent film for each respective signal frequency.

2. The method according to claim 1, wherein said film is a transparent coating on a semiconductor substrate.

3. The method according to claim 2, wherein said semiconductor substrate is a die among a plurality of dies carried on a semiconductor wafer.

4. The method according to claim 3, wherein said beam of light is large enough to cover at least one complete die.

5. The method according to any of claims 1-4, wherein the intensity of the interference pattern of the light reflected from the upper and lower surfaces of the transparent film is detected for each wavelength.

6. The method according to any one of claims 1-5, wherein the intensity of the light reflected from the transparent film is detected by a spectrum analyzer having a photodiode detector for each wavelength.

7. The method according to any one of claims 1-6, wherein the thickness of the transparent film is measured *in situ* in real time with the application of the transparent film to the substrate; and the thickness measurement is used to control the application of the transparent film to the substrate.

8. The method according to any one of claims 1-7, wherein the transparent film is a photoresist film applied to a semiconductor substrate during the processing of the semiconductor substrate.

9. The method according to any one of claims 1-7, wherein the transparent film is an intermetal dielectric layer applied to a semiconductor substrate between two metal layers to dielectrically isolate the two metal layers.

10. The method according to any one of claims 1-6, wherein the thickness of the transparent film is measured *in situ* in real time with the removal of the transparent film from the substrate, and the measured thickness is used to control the removal of the transparent film from the substrate.

11. The method according to any one of claims 8-10, wherein the thickness of the transparent film is measured *in situ* in real time with the development of the photoresist, and the measured thickness is used to monitor the development rate of the photoresist.

12. Apparatus for measuring thickness variations of a transparent film on a substrate, comprising:

a) an illuminating device for illuminating the film with a beam of light of multiple wavelengths;

b) a detector for detecting the intensity of the light reflected from the transparent film for each wavelength;

c) and a processor:

(i) for producing a signal defining the variation of the intensity of the detected light as a function of the wavelength of the detected light;

(ii) for applying a Fourier Transformation to said signal to produce a series of Fourier coefficients for the signal frequencies of the Fourier Transformation; and

(iii) for determining from said Fourier coefficients the thickness of the transparent film for each respective signal frequency.

13. The apparatus according to claim 12, wherein said detector includes a spectrum analyzer for separating the reflected light into its different wavelengths, and a photodiode array including a photodiode detector for each wavelength.

14. The apparatus according to either of claims 12 or 13, wherein said semiconductor substrate is a die among a plurality of dies carried on a semiconductor wafer, and said beam of light is large enough to cover a complete die.

15. The apparatus according to any one of claims 12-14, wherein said detector detects the intensity of the interference pattern of the light reflected from the upper and lower surfaces of the transparent film for each wavelength.

16. The apparatus according to any one of claims 12-15, wherein said apparatus further comprises a supporting surface for supporting said substrate, and a rotary drive for rotating said supporting surface while the substrate thereon is illuminated by said illuminating device, and while the intensity of the reflected light is detected by said detector.

17. The apparatus as claimed in any one of claims 12-16, wherein the apparatus further includes a film applicator for applying said transparent film to the substrate, and means for controlling said film applicator in real time in response to the measured thickness of the transparent film.

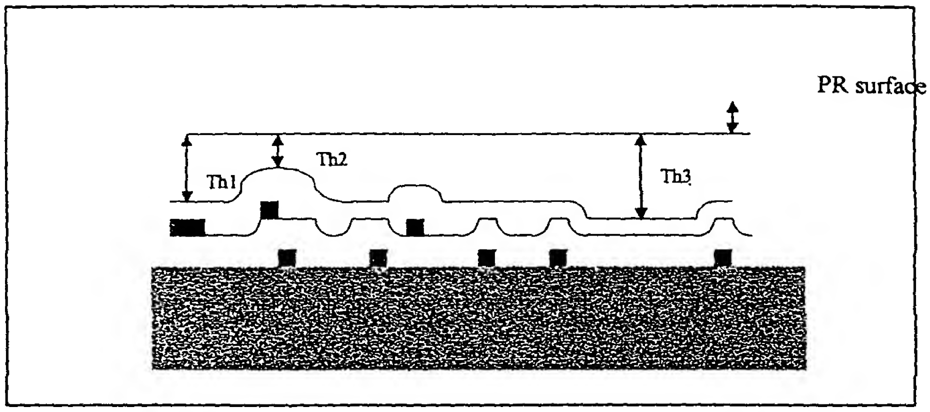
18. The apparatus according to claim 17, wherein said coating applicator applies a photoresist film on a semiconductor substrate.

19. The method of measuring thickness variations of a transparent coating on a substrate according to any one of claims 1-11, substantially as described with reference to and as illustrated in the accompanying drawings.

20. Apparatus for measuring thickness variations of a transparent film on a substrate according to any one of claims 12-18, substantially as described with reference to and as illustrated in the accompanying drawings.

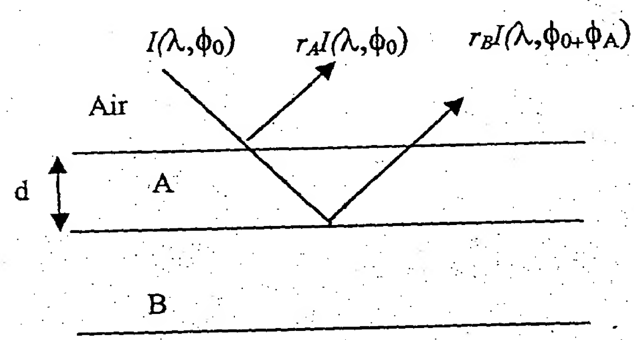
For the Applicant

Eitan, Pearl, Latzer & Cohen Zedek
Advocates, Patent Attorneys & Notaries
P-1805-IL



PR surface
Th1
Th2
Th3

Fig. 1



$I(\lambda,\phi_0)$
$r_A I(\lambda,\phi_0)$
$r_B I(\lambda,\phi_{0+}\phi_A)$
Air
d
A
B

Fig. 2

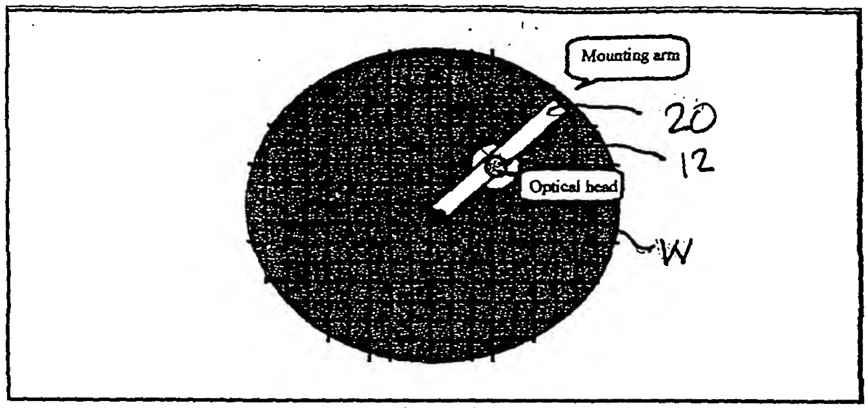


Fig. 5

Top view of the coated wafer and the TMD.

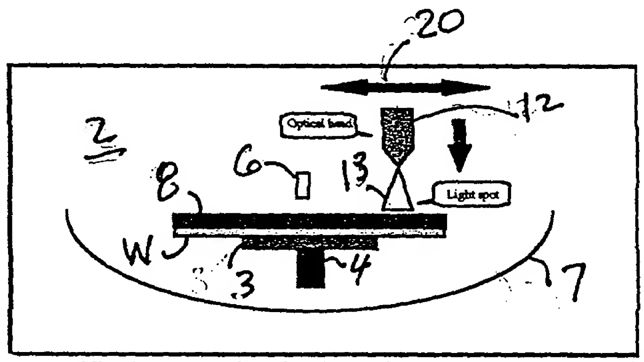
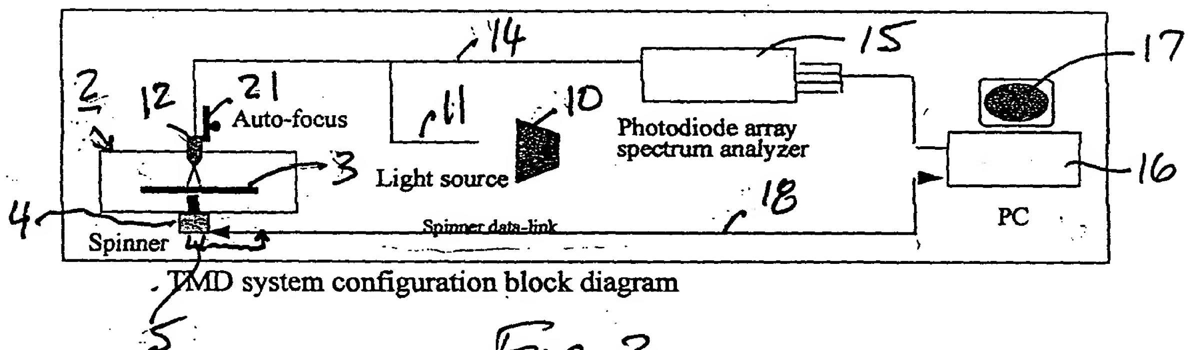


Fig. 4

TMD mounting in the spinner system -side view

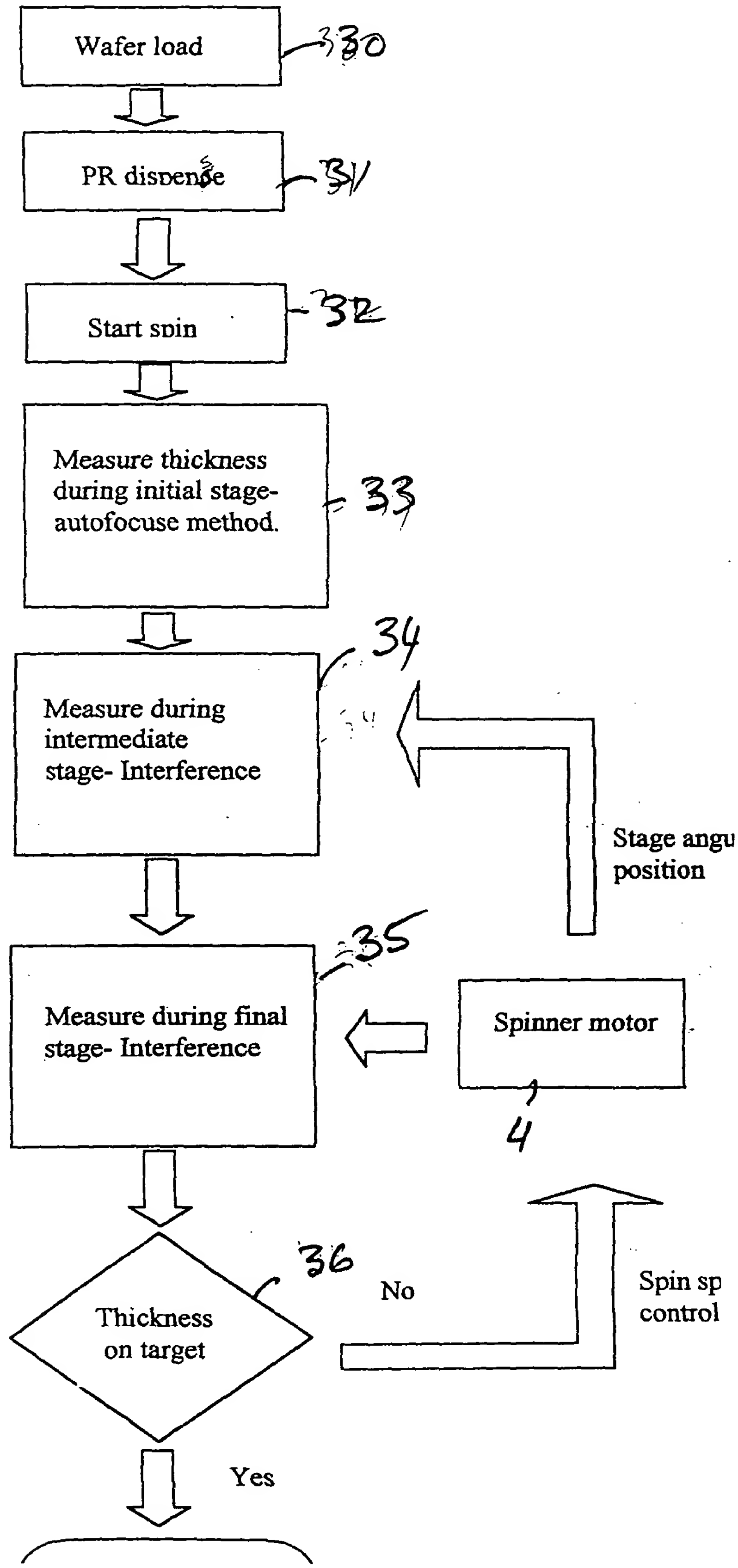


TMD system configuration block diagram

Fig. 3

Thickness control during spin – Flow chart

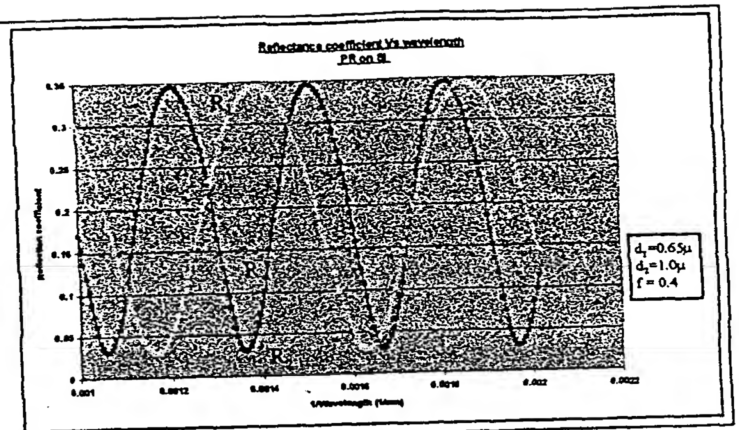
Fig. 6



$R_1 = R_1(\lambda, d_1)$

$R_2 = R_2(\lambda, d_2)$

$R = f R_1 + (1-f) R_2$



Reflectance coefficient as function of wavelength for two different thickness and the combined coefficient.

Fig. 7

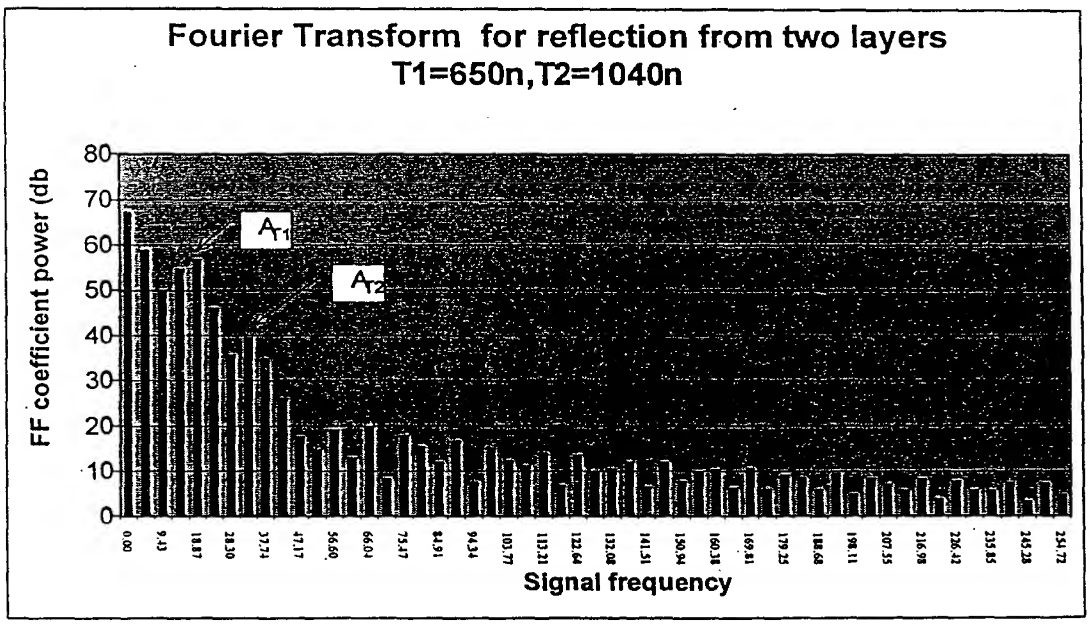


Fig. 8

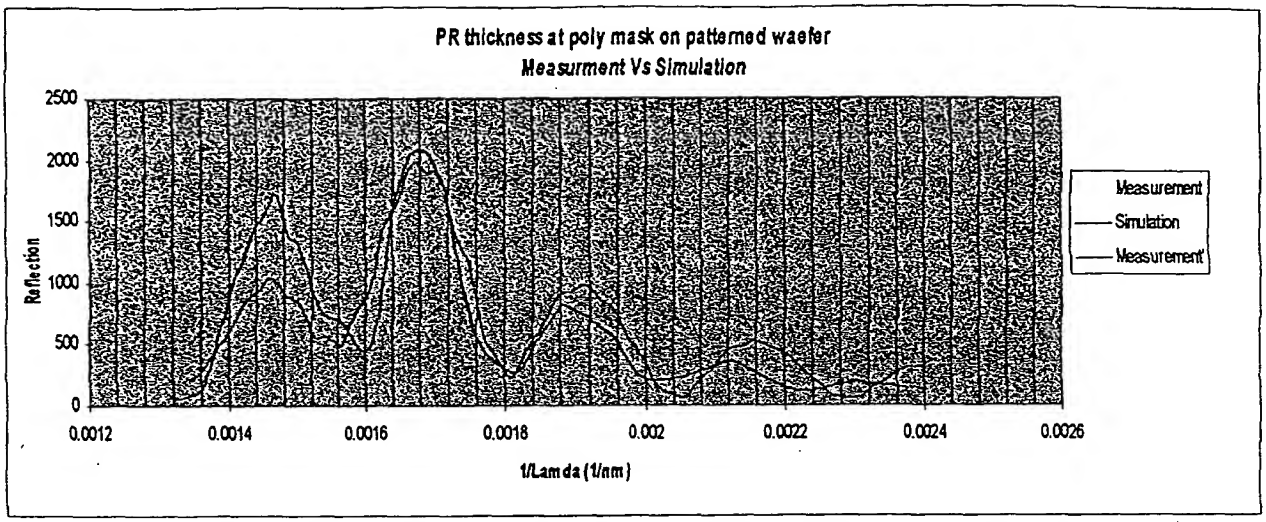


Fig 11.1 Reflected Signal Vs theoretical signal of P.R on Wafer at the 4th mask step.

Fig. 9

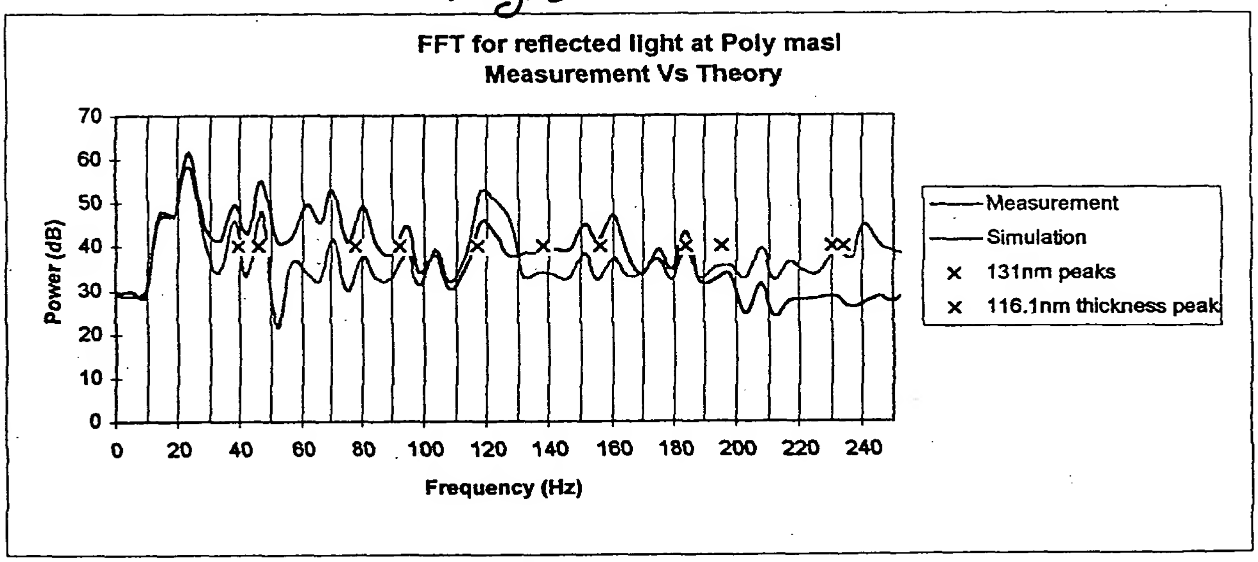


Fig 11.2 FFT of the signals in fig 11.1 – Measured Vs theoretical.

Fig. 10